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Progressive failure along frictional discontinuities

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ABSTRACT

The most important mechanism for deformation and failure in rock masses under relatively low stresses is slip along pre-existing discontinuities. These discontinuities can be viewed as fractures and their behavior can be approximated using Linear Elastic Fracture Mechanics theory. Slip along a frictional discontinuity can be approached as initiation and propagation of a mode II fracture along its own plane. Fracture mechanics theories predict that under pure mode II loading initiation will occur when the energy release rate of the fracture attains a critical value (GIIC), which is generally taken as a material property. The research conducted shows that this is not the case. Identification and quantification of the mechanisms for the onset and propagation of slip along frictional surfaces are carried out by testing in biaxial compression rock and rock-model specimens. The specimens consist of individual blocks with perfectly mated contact surfaces. The contact surface between blocks is equally divided in two areas, one with a lower frictional strength (weak area) and the other one with a higher frictional strength (strong area). Experiments show that slip starts first in the weak area and progresses toward the strong area with increasing load. Once slip has reached the strong area, a sharp contact is created between the area that has slipped (weak) and the area that has not (strong). Results from the tests show that the critical energy release rate, GIIC, depends on the frictional characteristics of the surface and on the critical displacement required to decrease the frictional strength from peak to residual. Furthermore, experiments conducted on surfaces with and without cohesion indicate that cohesive debonding and frictional mobilization may not occur simultaneously. Imaging of the discontinuity using wave propagation, as it undergoes slip, has been instrumental in detecting precursors to failure in the form of a distinct peak in the amplitude of transmitted waves and a marked decrease in the amplitude of reflected waves prior to the peak shear strength of a discontinuity. Seismic precursors are consistently observed well before slip, or failure, of the discontinuity.